SO_2 Detected on Callisto

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An 0.28 μm absorption feature has been detected in observations taken with the International Ultraviolet Explorer (IUE) on Callisto's leading and Jupiter-facing hemispheres (Lane and Domingue 1997). This feature is similar to the 0.28 μm feature observed on Europa's trailing hemisphere, which has been associated with sulfur dioxide. While the feature seen in observations of Europa is correlated with magnetospheric ion bombardment; the presence of the SO_2 feature on Callisto's leading side instead of trailing side argues against a direct magnetospheric-surface interaction process, as in the case of Europa.

Callisto's visible rotational light curves (Morrison et al. 1974, Nelson and Hapke 1978) do not indicate a smooth sinusoidal brightness reflection with longitude as seen on Europa and Ganymede and Callisto's hemispherical albedo dichotomy is opposite that of Europa and Ganymede. However, the darker leading side does not show a smooth sine function with a minimum visual albedo at 90^o longitude; instead there is a local minimum in the visible rotation curve at 60^o longitude which correlates with the longitude region of the Valhalla impact feature. The region for which IUE observed the strongest 0.28μm absorption also correlates with Valhalla's longitude, implying a possible impact or excavation origin for the SO_2 feature in this area.

The icy Galilean satellites are imbedded within the inner Jovian magnetosphere, albeit the densities of O and S ions are down by at least a factor of 20 at Callisto's orbit (Cheng 1986, Bagenal *et al*. 1992). Over long time scales the accumulation of energetic impacts should produce a near-UV signature similar to that observed on Europa and Ganymede, on which the trailing side has been darkened by ion impacts leading to the formation of UV absorbing molecules. The resultant molecules are seen more easily on Europa and Ganymede because they are present in a strongly UV-reflecting, relatively clean, water-ice surface. Callisto is far darker in its mean visible reflectivity (Nelson and Hapke 1978), making it more difficult to detect weak absorptions. Thus, there could be a magnetospheric absorption signature not yet detected at or near the central trailing longitudes, buried within the gray, very broadband darkening material found all over the Callisto surface. This, however, would not explain the preferential detection of the 0.28μm feature in the regions of the leading and Jupiter-facing hemispheres.

The visible light curves give evidence for at least one and possibly two additional processes leading to spatially inhomogeneous absorptions. Our detection of small quantities of S-O or SO_2 (0.28μm band) around the Jupiter-facing hemisphere (most easily detected around 60^o longitude) match the visible light curve darkening seen by Nelson and Hapke (1978) in that longitude region. But SO_2, as a frost in bulk, is bright in the visible down to 0.32μm. The brown, red, and black forms of S_x are dark in the visible. Given that the SO_2 signature we detected is not that of a bulk frost, we believe that the principal species responsible for the observations are either the *in situ* products formed from high velocity S or S_x flowing outward from the Io torus as high-speed neutral electron-recombination products formed near $6R_j$ and colliding with Callisto's water ice surface (Smyth 1992), or excavated and formed by modest to large size meteor impacts on Callisto's surface. Depending upon an ion's magnetospheric radial location at the time of neutralization, outward velocities could range from 50 to 150+ km/s

(Cheng 1986, Bagenal *et al*. 1992), producing a low density, high speed 'neutral wind' outflowing from the Io. The direction of this 'wind' when vectorially combined with Callisto's ~8 km/s orbital velocity, produces an impingement zone that is biased towards the Jupiter-facing hemisphere. As has been postulated to occur at Europa, the high speed S_x impacts disrupt the surface water ice lattice, and when the incoming neutral has lost its translational energy, the S or S_x sits in a disturbed lattice. Atomic S can form weak bonds with the nearby O atoms, whereas S_x would have a far lesser interaction (electron covalency shells filled), and thereby keep its own spectral signature (mostly visible absorption in the blue-green wavelength region with no UV features). The spatial co-existence of these material would explain both the near-UV signature and Callisto's visible albedo behavior in the 310^o to 90^o longitude region. S_x is stable (not reactive) in water ice at 120K. If a meteor impact were to occur shock heating of the Callisto's outer surface would probably produce temperature impulses of >1sec well in excess of 500K leading to reactions of S_x with hot volatilized water. One product would be SO_2. IUE's spatial resolution is insufficient to discern individual craters, therefore the detection of impact produced SO_2 by IUE requires either a very large impact, such as Valhalla, or a number of very strong, localized impact-produced concentrations. UV measurements from the Galileo spacecraft should resolve this enigma.

References

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